

Energy Storage

Development of Advanced Cathodes

Background

Performance, affordability, and safety of batteries for electric vehicle and hybrid electric vehicle applications must continue to be improved for widespread use. The challenge to engineer battery materials that can withstand large fluctuations of composition, volume, and temperature over many, many cycles without loss of integrity and electrical continuity is formidable. A team of materials scientists at the Oak Ridge National Laboratory (ORNL) is focused on developing new composite electrode architectures and materials that may improve the thermal stability and cycleability of the battery cathode. For advanced lithium-ion batteries, cathodes composed of LiFePO_4 coated graphite foams are being evaluated. In addition, for the lithium-sulfur battery system, sulfur-copper composites have been studied.

Technology

Graphite foams pioneered at ORNL are expected to be

superior current collectors for a variety of rechargeable battery chemistries due to their exceptional thermal and electrical conductivities, light weight, high surface area, and chemical stability. As the current collector for LiFePO_4 based cathodes, we estimate that a dense, thin coating of LiFePO_4 over the exposed and interior surfaces of a graphite foam sheet will give a capacity comparable to

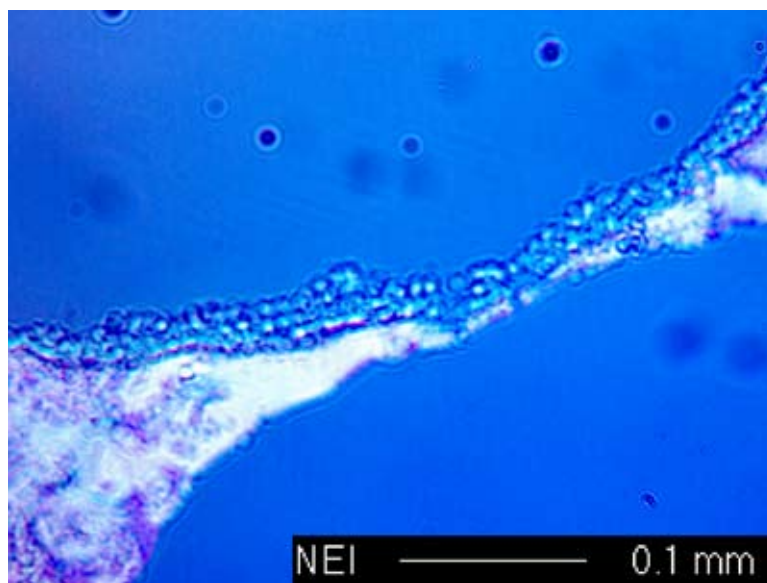


Figure 1. Optical micrograph showing the cross-section of a LiFePO_4 -coated graphite foam cathode. A graphite wall separates two large pores; the top surface of the wall is coated with a 30 μm -thick layer of LiFePO_4 particles.

Benefits

Advanced materials and designs for battery cathodes, formed as composites of the active and conductive materials, will improve cycle stability and thermal management of lithium batteries, without excessively compromising the high energy densities needed for vehicle applications.



that of conventional battery cathodes, yet the foam will provide superior thermal and electronic transport throughout the electrode.

To date, promising cycling has been achieved for LiFePO_4 slurry coated carbon foam prepared by a vendor, although the coatings are not uniform or as thin as needed. Advanced formulations and coating techniques are being developed at ORNL. With the graphite foams, the LiFePO_4 coating can be strongly bonded to the current collector via conventional heating or possibly by microwave processes, rather than simply pressed onto a metal foil as for conventional battery fabrication.

The theoretical energy density for lithium-sulfur batteries far exceeds that currently achievable in the lithium-ion systems. Because sulfur has a high electronic resistivity, it is essential to add a fine dispersion of a conductive additive, typically carbon black. Work to date shows that replacing the carbon additive with copper or copper sulfide will give a sulfur electrode with comparable theoretical energy density, but with potentially superior cycleability and higher utilization of the capacity. This is due to the high electronic conductivity and electrochemical activity of the Cu_2S and CuS phases. Copper sulfides have been prepared by electrochemical sulfidization of copper foils, films, and fibers. Composites of

elemental sulfur and copper sulfides show good cycling for one or two cycles, but then deteriorate due to solubility of lithium sulfides in the electrolyte solution. The key challenges for future work require suppression of this dissolution and development of more robust composite architectures able to accommodate the volume changes during cycling.

Status

Future efforts will include development of new synthesis routes for superior LiFePO_4 coatings of the carbon foam. Using graphite foam, we hope to demonstrate effective thermal management for Li-ion batteries, without compromising the energy and power densities. Further improvement may be achieved by tailoring the density, cell size, and pore size for the foam morphology to maximize performance.

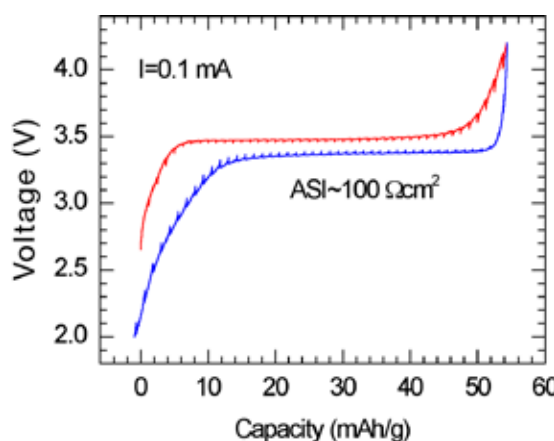


Figure 2. Charge/discharge cycle of a LiFePO_4 -coated graphite foam cathode vs a lithium anode. Periodic relaxation of the battery during the cycle shows a low area-specific impedance.

Contacts

Nancy Dudney
Oak Ridge National Laboratory
(865) 576-4874
dudneynj@ornl.gov

Tien Duong
Vehicle Systems Technologies Team Lead
Department of Energy
(202) 586-2210
tien.duong@ee.doe.gov

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